ATIC EXPERIMENT: ELEMENTAL SPECTRA FROM THE FLIGHT IN 2000

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Abstract

The Advanced Thin Ionization Calorimeter (ATIC) program files a fully active Bismuth Germanate (BGO) calorimeter preceded by a 0.75 interaction length graphite target with a silicon charge detector, to measure the charge and energy of cosmic ray nuclei. ATIC is intended to measure elemental spectra of nuclei from hydrogen to iron, with energies from $\sim$ 30 GeV - 100 TeV. ATIC has been flown in two Long Duration Balloon (LDB) flights in 2000 and 2002. In this paper we present preliminary results from the first flight, which was a test flight that lasted for 16 days, starting on 12/28/00.

1. Introduction

ATIC is a balloon borne experiment designed to investigate the charge and energy spectra of Z = 1 to 28 cosmic rays over the energy range $\sim$ 30 GeV - 100 TeV. ATIC collected 45 GB of science data during its first LDB flight in Antarctica from 12/28/00 to 01/13/01. In this paper we present a brief description of ongoing analysis and preliminary energy spectra of protons and helium. Various issues that arose in extracting elemental spectra from the first flight are discussed.

2. ATIC Instrument

The ATIC instrument has three types of detectors to measure the charge, energy and trajectory of incident cosmic rays [5]. At the top of the instrument is a silicon matrix (80 $\times$ 56 pixels) with total active area 0.95 $\times$ 1.05 m^2 for

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determining charge of the incident particles. Three scintillator hodoscopes (S1, S2 and S3) which are interleaved with a flared graphite interaction target provide a fast pre-trigger and help in trajectory reconstruction. S1, S2 and S3 have 42, 35 and 24 strips of dimensions $2 \times 1 \times 88.2$ cm^3, $2 \times 1 \times 74.2$ cm^3 and $2 \times 1 \times 52.4$ cm^3, respectively. The calorimeter consists of eight layers of 40 BGO crystals, each with dimension $2.5 \times 2.5 \times 25$ cm^3.

3. Analysis

3.1. Detector Response: To make the detector response as independent of the incident energy as possible, good events are defined as being within the geometry and interacting near the top of the instrument. The raw geometry factor was calculated to be 0.25 m^{2}sr by requiring the within-geometry events to pass through S1, S2, S3 and the upper 6 layers of the BGO stack. The effective geometry factor (GF_{eff}) was calculated to be 0.18 and 0.23 m^{2}sr, respectively, for proton and helium by further requiring the events to interact before they pass the second layer of the BGO stack. According to GEANT/FLUKA 3.21 simulation with isotropically incident protons, the mean deposited energy was 36% of the incident energy, and the corresponding energy resolution was 41% when the incident energy was 1 TeV. For incident energy from 100 GeV to 100 TeV the energy resolution is quite constant, while the fraction of the mean energy deposit shows only a slight energy dependence due to increase in shower leakage from the calorimeter at higher energy [7].

3.2. Event Selection: Several selection criteria were applied to keep high efficiency for good events while effectively reducing the level of background events:

1. The reconstructed trajectory was required to be within the fiducial volume of the ATIC instrument to remove out-of-geometry events.

2. The SNE (sum of normalized energy) of the reconstructed trajectory [2] was required to be larger than 5, in each of x, y directions, to ensure the trajectory is along the shower axis. SNE is defined as the sum of normalized energy of the detector segments that participate in the trajectory reconstruction in each layer. The energy is normalized to the maximum energy in the corresponding layer.

3. The first BGO layer was required to have less than 25% of the total energy deposit to remove side-exit events.

4. Each of the BGO layers was required to have an energy deposit larger than 125 MeV to remove non-interacting and late-interacting events.

5. Of the 8 BGO layers, at least 3 even numbered and 3 odd numbered layers were required to have more than 3% of the total energy deposit to verify sufficient deposited energy for trajectory reconstruction in both x-z and y-z.

When these selection criteria were applied to the proton simulation data, 90% of good events survived, with 5% background remaining in the selected sample at 100 GeV with slightly more background at higher energy (9% at 100 TeV). The efficiency (ε) of the event selection was estimated to be 40% and 42% for protons and helium, respectively, from the remaining fraction of the selection criteria. A major part of the inefficiency was due to failure of trajectory reconstruction when the incident particle passed through dead channels or dead materials of the hodoscopes.

3.3. Normalization: Proton and helium events were seperated and counted from the charge distribution based on the ionization signal in the Si matrix, as shown in Fig. 1. The counts (ΔN) of the proton and helium candidates in each energy bin (ΔE) were normalized to obtain the differential fluxes (F), given by

$$F = \frac{\Delta N \cdot (1-\delta)}{\Delta E \cdot \mathrm{GF}_{\mathrm{eff}} \cdot \varepsilon \cdot T \cdot \eta}, \tag{1}$$

where δ is the background contamination, T is the live time (312 hours), and η is the correction factor of atmosphere attenuation loss (0.94 for proton and 0.89 for helium, assuming the amount of residual atmosphere above ATIC to be 5 g cm^{-2} and using the cross-section parameterization in [8]).

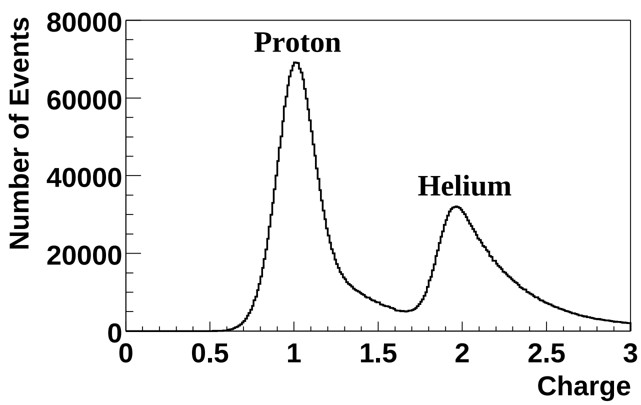

Fig. 1. Charge distribution for hydrogen and helium from the ATIC 2000 flight, measured by Si matrix, after event selection.

4. Results

The procedure described above was used to obtain preliminary proton and helium spectra as shown in Fig. 2. Despite the fact that there are more corrections expected in the near future (e.g. correction for trigger efficiency below a few hundred GeV, full incorporation of the difference between proton and helium, de-convolution, etc.), the result shows a major improvement in statistics over the energe range $10^2 \sim 10^4$ GeV. Previously, Ryan et al. measured only lower part of

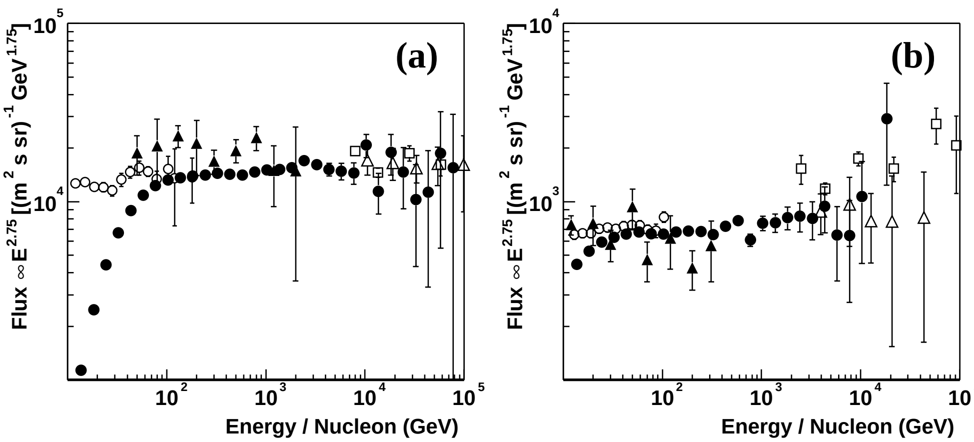

Fig. 2. Preliminary spectra of (a) proton and (b) helium measured by ATIC-1 (filled circles), along with other measurements (open circles for AMS [1], filled triangles for Ryan et al. [6], open squares for JACEE [4], and open triangles for RUNJOB [3]). Below a few hundred GeV, ATIC-1 data shows the effect of trigger efficiency that is yet to be corrected.

this energy region. Our measurements filled the gap between the results reported by AMS, JACEE and RUNJOB. The results are in general agreement with earlier observations.

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